Princeton Plasma Physics Laboratory Procedure		
Procedure Title: NSTX-U Coil Energization Tests		
Number ISTP-NSTX-001	**Revision: 6**	Effective Date: Expiration Date: *(2 yr. unless otherwise stipulated)*

Procedure Approvals	
Author	Date
ATI	Date
RLM	Date

Responsible Division:

Procedure Requirements
designated by RLM

LABWIDE:

	Work Planning Form #_____(ENG-032)		Lockout/Tagout (ESH-016)
	Confined Space Permit (5008, Sec. 8, Chap 5)		Lift Procedure (ENG-021)
	Master Equip. List Mod (GEN-005)		ES&H Review (NEPA, IH, etc.)
	RWP (HP-OP-20)		Independent Review
	ATI Walkdown		Pre-job Brief (ENG-030)
	Post-job Brief		Hazard Analysis
X	Run Copy Required (performance of procedure must be documented and archived per ENG-030 page 10)		Special archiving requested for completed Run Copies:_____

D-SITE SPECIFIC:

	D-Site Work Permit (OP-AD-09)		Door Permit (OP-G-93)
	Work on Tritium Contaminated Sys. (OP-AD-77)	X	Activity Certification Committee Review
	Pre-job brief (ENG-030)		T-MOD (ENG-036)

REVIEWERS (designated by RLM)
Accountable Technical Individual _____
Test Director _____
Independent Reviewer _____
D-Site Shift Supervisor _____
NSTX **A. Von Halle**
TFTR Caretaking _____
Vacuum _____
Computer _____
Tritium _____
Quality Assurance/Quality Control _____
AC Power _____
Maintenance and Operations Division _____
Energy Conversion System/MG System **S. Ramakrishnan**
Environmental Restoration & Waste Management Division _____
Water _____
Neutral Beam (Heating Systems Branch of Electrical Engineering) _____
Radiofrequency (Heating Systems Branch of Electrical Engineering) _____
Diagnostics _____
Environmental, Safety, & Health _____

TRAINING (designated by RLM)

No training required ☒ Instructor _____

Personnel (group, job title or individual name)	Read Only	Instruction	Hands-On
_____	☐	☐	☐
_____	☐	☐	☐

Training Rep. _____

RLM _____

1. PURPOSE

1.1 This procedure provides a means for documenting and implementing changes to the operating envelope and protection system settings for the NSTX magnet systems.

1.2 This procedure is intended to be repeated multiple times as the operating envelope of the machine is adjusted to support the experimental program.

2. SCOPE

2.1 The scope of this procedure includes:

- definition of allowable operating envelope for coil power supply systems
- testing with individual circuit energization
- testing with multiple circuit energization (combined fields)

2.2 The following additional steps are (optionally) invoked:

- exercise of protective features
- confirmation of voltage induced in circuits not under test
- archival of magnetic diagnostic response
- other special tests/measurements as circumstances may dictate

2.3 This procedure is not intended to produce a plasma in the NSTX device. To prevent plasma formation during test shots, high vacuum conditions will be maintained and gas injection pulse valves will not be operated.

3. REFERENCES

OP-NSTX-17	Pulse Duration & Period (PDP) Trip Control Settings
OP-PC-734	ECS Thyristor Rectifer Reactivation
PTP-ECS-39	FCPC Dummy Load Tests
D-NSTX-OP-G-141	Changing Polarities on NSTX Coil Systems
OP-DCPS-779	DCPS Set-Up/Start-Up Procedure

4. RESPONSIBILITIES

Head of NSTX Engineering Ops: Shall appoint Test Director, and approve operating levels called out herein.

Run Copy Head of NSTX Engr. Ops: _____ *Init.* _____

Chief Operating Engineer (COE): Overall responsibility for machine operations, and preparation of machine and ancillary systems in advance of testing.

Run Copy COE: _____ *Init.* _____

Test Director: Overall responsibility for conduct of tests, and documentation of results in the form of a Test Record (completed Run Copy, Test Data Sheets, and any other relevant data or information collected during the tests).

Run Copy Test Director: _____ *Init.* _____

Protection Engineer: Responsible for setting coil protection devices including the Digital Coil Protection System (DCPS).

Run Copy Protection Engineer: _____ *Init.* _____

FCPC Engineer-In-Charge (EIC): Responsible for configuration and operation of power supply systems, including protection settings in power supply fault detectors.

Run Copy EIC: _____ *Init.* _____

5. PROCEDURE

5.1 Head of NSTX Engineering Operations shall indicate allowable NSTX operating levels and bus link constraints in Tables 1 through 6.

Table 1 - Current Allowables

	Imin (kA)	Imax (kA)	Coil I Rated (kA)	Link Polarity (see note)	PS I Rated (kA)	$\int i^2(t)dt$ (kA2-sec)	$\int i^2(t)dt$ rated (kA2-sec)
OH			24		+24/-24		846.7
PF1aU			19		+19		1985.5
PF1bU			13		+13		356.6
PF1cU			16		+16/-8		1098.2
PF2U			15		+15/-11		1237.5
PF3U			16		+12/-16		1408
PF4			16		+16		1408
PF5			34		+34		635.8
PF3L			16		+12/-16		1408
PF2L			15		+15/-11		1237.5
PF1cL			16		+16/-8		1098.2
PF1bL			13		+13		356.6
PF1aL			19		+19		1985.5
TF			130		+130		118,976
RWM			5		+/- 3.333		66.6

Note: F = forward only, R = reverse only, F or R = forward or reverse

Table 2 – Minimum Pulse Repetition Period

	Minimum Pulse Repetition Period (seconds)	Rated Pulse Repetition Period (seconds)
TF, PF, and RWM Coils (except OH), and CHI		300

Table 3 – OH Repetition Rate Constraints

Pulse Repetition Period (seconds)	Maximum $\int i^2(t)dt$ (kA2-sec)	Maximum $\int i^2(t)dt$ (% of 600 sec value)	Minimum Starting Temperature (degC)
600		100	
450			
300			

Table 4 - Series PSS (Voltage) Allowables

	#Series PSS Allowable	#Series PSS Rated Maximum (≈ kV)
OH		6 (4 during combined OH/CHI) (2 Parallel)
PF1aU		2
PF1bU		2
PF1cU		2
PF2U		2
PF3U		2
PF4		2
PF5		3
PF3L		2
PF2L		2
PF1cL		2
PF1bL		2
PF1aL		2
TF		1 (8 Parallel)
RWM		1

5.2 Constraints on Independent Control of individual magnets sets have been established in DCPS. Mechanical Limit Conditions have been defined and set in DCPS algorithms.

Head NSTX Engineering Operations *Init.* _____

Table 5 – Protective Feature Settings Headroom

	Overcurrent	$\int i^2(t)dt$
PSRTC	0%	0%
$DCPS_{FCC}$	2%	0%
$DCPS_{JA}$	5%	1%
FD	10%	Not applicable

5.3 Test Sequence

5.3.1 Preliminaries

a. Generate Test Data Sheets for each shot to be performed under this run copy of this procedure (template for TDS attached in Appendix hereto). Develop appropriate PSRTC files and perform simulations.

Test Director *Init.* _____

b. Confirm that the DCPS is configured for testing per OP-DCPS-779

Head NSTX Engineering Operations *Init.* _____

c. Confirm settings of ECS Thyristor Rectifiers Fault Detectors (FD) are consistent with current levels called for herein and/or TDS initial trip levels, in accordance with OP-PC-734 and tested in PTP-ECS-39. Nominal headroom over the allowables is given in Table 5.

FCPC EIC *Init.* _____

d. Confirm configuration of power supply system is consistent with polarities and levels indicated in TDS. Execute link change procedure D-NSTX-OP-G-141 if Table 1 differs from existing conditions.

FCPC EIC *Init.* _____

e. Confirm settings of Pulse Duration and Period (PDP) trip controls: OP-NSTX-17.

Protection Engineer *Init.* _____

f. Review T-Mod log and confirm that T-Mods in place will not compromise the execution of the tests called for herein.

COE *Init.* _____

5.3.2 Steps Preceding Each Test Session

Following steps, as applicable, shall be performed each time a new test session is started and documented in the Test Record.

a. Perform scrub and inspection of NTC per OP-NSTX-01 "Preparations of Experimental Areas for Machine Operations".

b. Perform daily startup activities per OP-NSTX-14 "NSTX Operations Guide for Startup and Shutdown".

c. Start up FCPC and Coil Cooling Water systems. Record conductivity of both deionized water systems.

d. Clear and secure all experimental areas per OP-AD-117 "Access Control Procedure". Via HIS, “Enable” all systems, pressurize SLD and place all systems in “Configure”.

e. Using methodology of OP-ECS-245, "FCPC Daily Startup/Shutdown Procedure", perform 500V hipot of all coil systems with power supply system disconnected (SDS open).

f. If/when MG is required, start MG system at 13.8kV, 65Hz.

COE *Init.* _____

5.3.3 Steps Associated With Each Test Shot

Execute the test shots called out in the Test Data Sheet (TDS) (attachment1) and perform the following additional steps as called out therein.

a. Induced Voltage Confirmation

When called out on the TDS, the PSRTC coil voltage simulation results shall be compared to the digitized coil voltage transducer signals for shape, scale, and polarity.

b. Diagnostic Calibration Shot

When called out on the TDS, the acquired diagnostic calibration data shall be examined by the Physics Operator and confirmed to be complete prior to declaring the test step complete. If not, the shot shall be repeated.

c. Additional tests and measurements may be noted on the TDS in the "Other Special Requirements" section. This may include monitoring of special instrumentation (thermocouples, strain gauges, motion transducers, etc.) as called out by the Test Director, or if testing requires a combined coil set to test an individual coil's protection features.

d. Protective Feature Tests

The TDS is set up to record the listed Protective Feature Tests for single magnetic circuits over a series of test shots. Each TDS is assigned a sequence # which is recorded on the Test Plan spread sheet with a summary of the test shot results. Test shots should begin at a low current level selected by the Test Director (typically 10%) and record this shot # as PSRTC Current Setting (1). Load parameter trees into the DCPS for each of the $DCPS_{FCC}$, $DCPS_{JA}$ protection settings described in table 5 for a PSRTC Current Setting (1), and then increase the PSRTC current settings and set up DCPS parameter trees on subsequent shots to exercise each of those protection settings. (note: The Fault Detector [FD] settings have already been exercised during the rectifier dummy load tests).

Re-load new parameter trees for the DCPS Protection settings per Table 5 assuming a PSRTC current reference 10% LESS than the final desired coil current. At this point also reduce the Rectifier Fault Detector Overcurrent and Overtime Limits to ~ 15% LESS than specified per Table 5. Conduct a test shot at ~ 50% of the final desired coil current and record this shot # as PSRTC Set (2). Increase current in subsequent test shots and set up DCPS parameter trees and the rectifier fault detector settings to exercise each of the $DCPS_{FCC}$, $DCPS_{JA}$, or FD protection settings individually. Record test trip levels and shot #'s on the TDS.

Finally, load the DCPS parameter trees and set the fault detector trip levels for the final desired coil current with the headroom as listed in Table 5, and record the settings on the TDS. Complete a full current test shot and record the shot # on the TDS.

Select appropriate levels for the daily 50% and 100% test shots and record on the TDS.

Obtain approvals of test data sheet results and daily test shot level selections as listed on the TDS

5.3.4 Completion Steps

a. Update EPICs page with latest operating limits.

Test Director *Init.* _____

b. Confirm final settings of ECS Thyristor Rectifiers Fault Detectors (FD) are consistent with current levels called for herein, in accordance with OP-PC-734/PTP-ECS-39. Attach settings sheet.

FCPC EIC *Init.* _____

c. Confirm final settings of $DCPS_{FCC\ \&\ JA}$ are consistent with current levels called for herein. Confirm PDP settings per OP-NSTX-17.

Protection Engineer *Init.* _____

d. Place run copy in Operations Center.

Test Director *Init.* _____

APPENDIX

• Test Plan Template

• Test Data Sheet Template (Attachment 1)

Test Data Sheet #	OH (kA)	PF1aU (kA)	PF1bU (kA)	PF1cU (kA)	PF2U (kA)	PF3U (kA)	PF4 (kA)	PF5 (kA)	PF3L (kA)	PF2L (kA)	PF1cL (kA)	PF1bL (kA)	PF1aL (kA)	TF (kA)	RWM (kA)	DCPS-FCC OC	DCPS-FCC I2T	DCPS-JA OC	DCPS-JA I2T	FD OC	FD OT	Ind. Volt.	Mag. Diag Cal.	#Shot
																							Σ	0

Daily Test Shots	OH (kA)	PF1aU (kA)	PF1bU (kA)	PF1cU (kA)	PF2U (kA)	PF3U (kA)	PF4 (kA)	PF5 (kA)	PF3L (kA)	PF2L (kA)	PF1cL (kA)	PF1bL (kA)	PF1aL (kA)	TF (kA)	RWM (kA)
50%															
100%															

Notes:

APPROVALS

Test Director _____

NSTX-U Project Director _____

NSTX-U Project Engr. _____

Head, PPPL Eng _____

Head, Engr. Ops. _____

Head, Exp. Research Ops. _____

Example: Test Plan Template

D-Site	PRINCETON PLASMA PHYSICS LABORATORY	Attachment 1 TEST DATA SHEET	ISTP-NSTX-001 Rev 6 Page 1 of 1

Test Data Sheet Sequence # _____

® Induced Voltage Confirmation
® Diagnostic Calibration Shot

Protective Feature Tests (applicable to single circuit tests only):

® PSRTC Current Setting ® PDP Trip Setting
® $DCPS_{FCC}$ Overcurrent ® $DCPS_{FCC}$ $\int i^2(t)dt$
® $DCPS_{JA}$ Overcurrent ® $DCPS_{JA}$ $\int i^2(t)dt$
® Fault Detector Overcurrent ® Fault Detector Overtime

Other Special Requirements:

	OH	PF1aU	PF1bU	PF1cU	PF2U	PF3U	PF4	PF5	PF3L	PF2L	PF1cL	PF1bL	PF1aL	TF	RWM
# Series PSS															
# Parallel PSS															

MG Required: ® Yes ® No

Circuit Allowable Current		kA
Circuit Allowable I2T		kA^2-sec

Protection System	$DCPS_{FCC}$	$DCPS_{JA}$	**FD**	**Units**
Overcurrent Initial Setting				%
Overcurrent Initial Setting				kA
Overcurrent Final Setting				%
Overcurrent Final Setting				kA
I2T Initial Setting			n.a.	%
I2T Initial Setting			n.a.	kA^2-sec
I2T Final Setting			n.a.	%
I2T Final Setting			n.a.	kA^2-sec
Overtime Initial Setting	n.a.	n.a.		sec
Overtime Final Setting	n.a.	n.a.		sec

® PSRTC Current Set (1) Shot # _____ ® PSRTC Set (2) Shot # _____
® $DCPS_{FCC}$ Overcurrent Shot # _____ ® $DCPS_{FCC}$ $\int i^2(t)dt$ Shot # _____
® $DCPS_{JA}$ Overcurrent Shot # _____ ® $DCPS_{JA}$ $\int i^2(t)dt$ Shot # _____
® Fault Detector Overcurrent Shot # _____ ® Fault Detector OT Shot # _____

Test Shot Complete: Shot # _____ *Test Director Init.* _____